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«Амурский государственный университет»

УЧЕБНО-МЕТОДИЧЕСКИЙ КОМПЛЕКС ДИСЦИПЛИНЫ

«Иностранный язык (углубленно)» (английский)

по направлению подготовки 010600.68 - «Прикладные математика и физика»

Утвержден на заседании кафедры иностранных языков
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Учебно-методический комплекс по дисциплине «Иностранный язык (углубленно)» (английский) для направления подготовки 010600.68 «Прикладные математика и физика». – Благовещенск: Амурский гос. ун-т, 2010.

Учебно-методические рекомендации ориентированы на оказание помощи магистрантам очной формы обучения по направлению подготовки 010600.68 «Прикладные математика и физика» для формирования знаний по основам библиографии. В комплексе отражены основные направления научной деятельности преподавателей факультета.

Video «Physics. Greatest discoveries»

Tasks

1. Practice flaps, glottal sounds and words with vowel and consonant omission.
2. Study the questions.
3. Translate the key-words. Practice the pronunciation of the key-words.
4. Make suggestions about the content of the text.
5.Watch the video twice and answer the questions.
6. Retell the video episode.

HOW IT'S MADE

Key words

1. Swiss — made in Switzerland;	55. to measure;
2. army knife, soldier's knife;	56. dimension;
3. entire;	57. slightly;
4. pocket-size;	58. to be off — to below satisfactory level;
5. package;	59. to fit into smth.;
6. multitool, multitasker, multipurpose;	60. trademark name;
7. kit;	61. to slide;
8. to date back to;	62. brass — alloy of copper and zinc;
9. original;	63. rivet —heavy pin;
10. century;	64. aluminum spacer;
11. version for sale;	65. flat;
12. general public;	66. spring — a metal elastic device that returns to its shape or position;
13. to come in-handy;	67. screw driver;
14. lost in the wilderness;	68. to stack — to put in order;
15. either way — in any case;	69. to tap smth down,
16. coil — roll;	70. hook;
17. stainless steel;	71. scissors;
18. press;	72. divider;
19. die — a device used for shaping metal;	73. wood saw;
20. to force the steel against the die;	74. corkscrew — devise for opening bottle e.g. of wine;
21. to punch out;	75. assembly — construction;
22. blade shape;	76. attachment;
23. to form;	77. bushing — holding devise;
24. finger groove — hollow for the finger;	78. incredible, incredibly;
25. to pull the blade out of the handle;	79. bundle;
26. mass-produced;	80. thick;
27. can opener;	81. to chop off;
28. pliers — a tool for pulling out nails etc;	82. to flush — to be the same level with snth.;
29. to load smth into smth.;	83. to flatten;
30. a mix of smth and smth;	84. to pull apart;
31. ceramic stone;	85. to grind the cutting edge;
32. friction;	86. to angle smth. under ... degrees;
33. to polish;	87. sharp;
34. to keep parts from smth.;	88. laser;
35. to stick together;	89. angled edge;
36. to activate;	90. to verify;
37. powerful;	
38. magnet;	
39. to extract;	

40. to smooth;	91. to sandwich smth between smth and smth;
41. significantly, Syn. — considerably;	92. to embed smth for tight installation;
42. weak;	93. a pair of tweezers;
43. dull;	94. toothpick;
44. to arrange smth on smth.;	95. to inspect;
45. mass conveyor;	96. to confirm;
46. to expose smth to intense heat;	97. to be in perfect condition;
47. a quick cool-down;	98. to spring out of the handle;
48. to toughen;	99. There's no room for error;
49. to harden, hardened;	100. to spring into action
50. to slim and trim;	
51. grinding station;	
52. liquid;	
53. to keep smth. cool;	
54. to ride a carousel to — to go around;	

Questions

1. How is a Swiss army knife described by the correspondent?
2. What is said about its history?
3. How is the knife meant for now?
4. What is done during the first stage of production?
5. What is the second stage of production?
6. What do they use the powder for?
7. How are the blades extracted from the vibrating mass?
8. What are the results of the process of the second stage: positive and negative?
9. What happens during the third stage? What does the process do to steel?
10. Where do the blades go at the forth stage? What does the green liquid do?
11. What happens after that? What problem will arise if the the dimensions are even slightly off?
12. What is the final operation with the blade?
13. What is the process of building a Swiss army knife:describe the whole process of assembling?
14. How are rivets secured?
15. How many tools do they pack into the knife? How thick is the knife? What kind of tool do they get as a result?
16. How do they make the razor sharp? What is the checking procedure of the blade?
17. How many parts are there in the handle? How is the final pressing done? What do they do it for?
18. What two things do they fit in when the knife is assembled?

Phonetic exercises

Taps

li**tt**le, la**t**er, kit in a pocket, wil**d**erness, pro**d**uction, i**t** also, bla**de** ou**t** of, pro**d**uced, vibra**t**ing, wa**t**er, pow**d**er, activa**t**e a, me**t**al, har**d**en, tha**t** exposes, compu**t**erized, fi**t** into, sli**d**e a, divi**d**er, a**dd** a, bla**de** on, incre**d**ibly, tha**t** it's on the mark, tigh**t** installation, ou**t** of the handle

Glottals

i**t** wasn'**t** long, i**t** continues, equi**p**ment, significan**t**ly, qui**ck** cool-down, sligh**t**ly, won'**t** fit into, follow**ed** by, tap i**t** down, migh**t** nee**d** one, call**ed** bushing, pa**ck**(ed) nine, thi**ck**, fla**tt**ens, pull apar**t**, pocke**t** knives, that it's on the mar**k**,

Omissions

nine**t**y, an**d** pliers, an**d** water, weak an**d** dull, an**d** trim, an**d** spring, an**d** a pair of, an**d** then, an**d** smaller, pack**ed** nine

Physics-Discovery-Video

Key words

1) profound questions;	31) to be based on;
2) the Universe;	32) observation;
3) to hold matter together;	33) to test smth;
4) strange force;	34) to involve;
5) gentle enough;	35) dropping balls of different masses;
6) to make an apple fall;	36) to see smth in action;
7) powerful enough;	37) to pay (=make) a visit to;
8) to walk the Moon in captive order;	38) micro gravity research;
9) discovery;	39) vacuum chamber;
10) unleashing the fearsome power of the atom;	40) to go ... feet into the ground;
11) uncovering the nature of light;	41) at different rates;
12) to reveal forces;	42) to pump off the air out of smth;
13) to hold the entire Universe together;	43) feather;
14) curiosity;	44) ball, ping-pong ~, golf ~;
15) to drive smb to do smth;	45) roughly = approximately;
16) to be around = exist;	46) air resistance; to overcome ~;
17) ancient Greeks;	47) vacuum tank;
18) nature;	48) to set up an experiment;
19) to obey a set of laws;	49) to check out fire extinguishers;
20) tremendous breakthrough;	50) helium;
21) to give smb a notion/notions about smth;	51) carbon dioxide;
22) to be dead wrong;	52) international space station;
23) to defy (=ignore);	53) to drop the vehicle down;
24) common sense;	54) to retrieve the experiment;
25) to fall (fall-fell-fallen);	55) challenge;
26) fast-faster-the fastest;	56) turning point;
27) heavy-heavier-the heaviest;	57) acceleration;
28) light-lighter-the lightest;	58) caused by;
29) conventional;	59) hammer;
30) wisdom, a bit of ~;	60) to hit the ground;

Names: Aristotle, Galileo Galilee, the Tower of Pizza, NASA Research Center, Cleavland, Ohio, Steve Simons,

Questions

1. What is physics?
2. What 3 questions does physics ask?
3. What does our need to understand inspire?
4. What are the greatest discoveries in physics?
5. What is the role of curiosity in our life? Is it new to us?
6. What did ancient Greeks do? How valuable was that?
7. What was the trouble with all this? Why was that?
8. What is the first discovery?
9. What was it believed 2000 years ago? How does the commentator classify it? What was it based on? Why did people believe that?
10. What happened in the 17th century? What did the testing involve?
11. What did the commentator do to see the experiment in action?
12. Who did he meet with? What is that person responsible for?
13. What device do they have there? How does it look like? What is it meant for?
14. What did Aristotle think according to Steve Simons? What example with different objects did Mr Simons demonstrate?

15. What did Galileo illustrate? What example did Steve demonstrate?
16. What kind of experiment was set up?
17. What two substances were tested? Which proved to be more effective?
18. How important was Galileo's challenge to Aristotle law? What did these experiments lead to?
19. What did the astronaut demonstrate?

Phonetic exercises

Taps

stu**d**y, how **d**oes, ma**tt**er, wha**t** is, or**d**er, grea**t**est, a**t**om; ligh**t** itself, curiosi**t**y, a se**t** of, ligh**t**er, a bi**t** of, Aristo**t**le, bu**t** in the, ou**t** of, ge**t** a, se**t** up, bo**tt**om, gravi**t**y,

Glotalization

wha**t** holds, ye**t** powerful, isn'**t** new, abou**t** how, grea**t** discovery, i**t** was believed, Gree**k** philosopher, differen**t** masses, me**t** with, proje**ct** manager, tha**t** goes, a**t** differen**t** rates,

Omissions

mos**t** profoun**d** questions, an**d** what is, and powerful, gen**t**le enough, mos**t** o**f** these notions, firs**t** great, thousan**d** years, objec**t**s, an**d** people, an**d** met with, four **h**un**dred**, we c**a**n, in**t**ernational

Universal Gravitation

Key-words

1. a legend;
2. to be relaxing in an orchard;
3. to see an apple fall;
4. simple incident;
5. to cause smb. to wonder;
6. to sail contentedly overhead;
7. the eureka moment insight,
8. gravitational force;
9. to act on smth. alike;
10. to be extended;
11. all the way out to the Moon;
12. to travel on a straight line in a space past the Earth;
13. the Earth gravitational force;
14. to pull the Moon towards smth.;
15. to keep the moon trapped in orbit around the Earth;
16. to apply to all bodies in a cosmos;
17. ebb and flow of Earth's oceans;
18. to feel the greater pull, to get pulled out a little;
19. to rotate;
20. recognition;
21. landmark discovery in science;
22. to be far from finished.

Proper names: Sir Isaak Newton, Spencer R. Weart

Questions:

1. What is the next great discovery?
2. When was Sir Isaak Newton born?
3. What does the legend about Newton have?
4. What did the simple incident cause him to do? What did he realize?
5. How did Spencer R. Weart classify this discovery?
6. How does the moon travel and why?
7. What law had Newton discovered? Why is it called universal?
8. What happens when gravitational force of the Moon acts upon the Earth?

9. What is the mechanism of ebb and flow of oceans?
10. What is the role of Newton's discovery?

Phonetic exercises:

Taps
Bo**d**ies, wa**t**er, grea**t**er, li**tt**le
Glotalization
New**t**on, tha**t** Galileo, grea**t**, abou**t** it
Omissions
New**(t)**on, to(**wa**)rds, ebb (**a**)n(**d**) flow

The second law of thermodynamics

Key-words

1. the science of thermodynamics	
2. heat, heat energy	16. to be wasted, wasteful
3. transformed into a mechanical energy	17. to coin the word
4. power driven machinery	18. the efficiency
5. Industrial Revolution	19. to be limited
6. to turn into an energy of motion	20. to be lost in the process
7. a crank, a piston, a turbine	21. to convert into a mechanical energy
8. to turn a loom, to make a fabric	22. a momentous insight
9. to move a boat through the water	23. to move along
10. to move a train down the rails	24. implicit in the gasoline
11. to get more .... for your dollar	25. to heat up the pavement, the tyres
12. for the amount of fuel	26. cylinders, engine block
13. heat engine, steam engine	27. to wear out, to corrode
14. energy exchange	28. to be a driving force behind smth.
15. boiler	29. to power the world into

Questions

1. What is the next great discovery?
2. What is the science of thermodynamics? What depended on it?
3. What can heat energy be turned into? What are the examples?
4. What is desirable now? What do people begin to study?
5. Who formulated the next great discovery? When? What does the law state?
6. What word did Glassius coin? What does it explain?
7. Is there a heat engine that is 100% efficient?
8. How much energy is actually used to move a car? Where does the rest of it go
9. What was the second law of thermodynamics for the Industrial Revolution?
10. What did the next great discovery do?

Phonetic exercises:
Taps
wa**t**er**,** stu**d**ied, limi**t**ed, conver**t**ing, hea**t**ing
Glotals
hea**t**

Laws of motion

Key-words:

1. series of three books
2. to contain
3. to explain the movement of
4. to consider ice-hockey

5. to hit a hockey puck
6. to keep sliding off across the ice
7. to keep flying indefinitely
8. to kick the stick against the puck
9. to calculate
10. to get the force
11. to punch in the face
12. to equal
13. bold insight into the mechanics
14. to establish the foundation

Questions:

1. What is Sir Isaak Newton to many people? Why?
2. What is Newton's second great discovery?
3. What do these laws explain?
4. What helps to understand the laws?
5. What is the first law? How is it explained?
6. What is the second law? How is it explained?
7. What can you calculate using the second law?
8. What is the formulation of the third law?
9. What were three laws?
10. What did they establish?

Phonetic exercises:

Taps

pre**tt**y much

Glotalization

New**t**on, wro**t**e, grea**t** discovery, hi**t**, calcula**t**e

Electromagnetism

Key-words

1. one of the great engineering fit 2. the Hoover dam 3. height, to weigh 4. to produce electricity, to create ~ 5. a magnetic field, to create ~ 6. to figure out 7. to run an electric current through loops of wire 8. to turn on (off) electric current 9. to disappear 10. a book binder with an interest in electricity 11. to reverse the process 12. an electric generator in its basic form 13. a coil of wire btw. the poles of magnet 14. to move near each other 15. to pass through the wire 16. to keep somewhat cryptic notes on the experiments 17. to contribute to understanding 18. to prove invaluable	19. to find out more about 20. device 21. lightning, lightning safety 22. a giant birdcage 23. to be interrelated 24. to be worth smth. 25. to be distributed on a conducting surface 26. to be made of 27. to make sparks 28. to put a finger on the inside of the bar 29. to give it a try 30. to penetrate inside 31. go ahead 32. spectacular 33. to heat the cage, to strike the cage 34. to turn into 35. to push 36. satellite 37. modern communication 38. to inspire

Proper names: Michael Faraday, James Clerk Maxwell, Michael Alexander

Questions:

1. What is one of the great engineering fits of the XXth century? What is its height and weight?
2. What produces power? How much power is produced? How is electricity created?
3. What had scientists figured out? What is the result of it?
4. How can we create magnetic field?
5. Who was the first person able to reverse the process? When did it happen? How did it happen?
6. What is an electric generator in its basic form?
7. What did Faraday discover?
8. How does every electrical generator work?
9. What did Faraday keep? Whom did it help? How did he use them?
10. Where did the narrator pay a visit to? For what?
11. What was the device shown there used for? What does it look like?
12. Did the narrator agree to try it? What did he say?
13. What thing did Maxwell help us to understand?
14. What did Michael Alexander suggest the narrator to do? Was it safe?
15. Why did the narrator hope that Maxwell was right?
16. What was happening during the experiment?
17. What turned the cage into a giant magnet? What were other transformations?
18. What would the world be like without works of Faraday and Maxwell?
19. What did those scientists not know?

Phonetic exercises

Taps

grea**t**est, crea**t**ed, magne**t**ic, genera**t**or, li**tt**le bi**t**, me**t**al, conduc**t**ing, ma**d**e of, compu**t**er

Glottals

resul**t** is, somewha**t**, forge**t**, tha**t**

Omissions

seven **h**un**d**re**d** feet, scientist**s h**ad figured out

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Einstein – Relativity

Key-words:

1. a famous equation	13. to shoot a light beam
2. squared	14. to weigh less
3. to approach light speed	15. ratio
4. bizarre distortions	16. to hint at
5. to take place	17. enormous amount of energy
6. to beat slower	18. contained in a small quantity of matter
7. to contract	19. to throw at
8. to get heavier, to make heavier	20. to stand still
9. the energy of motion	21. gigantic leap
10. to turn into	22. a glimpse into a power of atom
11. to come from velocity	23. to digest
12. a flashlight	

Questions:

1. What is the next great discovery?
2. How does the professor explain the famous equation?

3. What does the energy of motion turn into?
4. Where does **m** in the equation come from?
5. What example does the speaker give with the flashlight? What is the ratio?
6. What does the equation hint at?
7. What happens when some object stands still?
8. What was this discovery for science?

Phonetic exercises

Flaps:

relativi**t**y, a**t** an enormous, ou**t** of, quanti**t**y, ma**tt**er

Glottalisation:

a**t** you, it's go**t**

Special Relativity

Key-words

1. scientific world	17. to the speed of light
2. to be turned upside down	18. to be separated
3. one of the revolutionary theories	19. an arrow, to fire~
4. to put forth	20. to deviate
5. to be presented to smb.	21. throughout the Universe
6. to be worthless	22. to speed up, to slow down
7. at the turn of the century	23. twin paradox
8. to be fussing about	24. rocketship
9. to be racing along a telegraph signal inside a wire	25. to send smb. off
	26. to accelerate near the speed of light
10. Earth shattering idea	27. to beat at different rates
11. to be inspired by the memory	28. to orbit astronauts
12. to be riding on a beam of light	29. to .affect smth..
13. to ponder	30. GPS satellite
14. to be fixed and absolute	31. accurate
15. to apply	32. to include relativistic effects
16. the approach	33. to be out of synchronization

Proper names: Switzerland, Bearn, Albert Einstein, Michio Kaku, Venice, Jupiter

Questions

1. When did the next great discovery happen? What did it do to the scientific world?
2. What did Einstein do? Was he famous at that time? Where did he work?
3. Where did the narrator pay a visit to? Why?
4. What did Einstein once say according to Michio Kaku?
5. What did Einstein do when he was a child? What was written in one book?
6. How did the scientist get his Earth-shattering idea?
7. What inspired Einstein when he was a teenager? What did he begin thinking about?
8. What did Einstein realize?
9. What did the scientist formulate?
10. What was the relation between space and time in Newton's world? What are the examples given?
11. What was Einstein's idea of time and space? What happens when time and space are changed?
12. How did Einstein demonstrate his experiment?
13. Why does the time beat at different rates? What is the principle formulated by the scientists?
14. What is the speed of the satellite? What is the example with two clocks?

Quantum theory

1. a quantum leap 2. proven to be 3. an enormous step in thought 4. subatomic particles, electrons 5. to move from one point to another 6. to occupy anyof the space in between 7. an impossibility in our everyday life 8. common place in 9. realm of the atom 10. subatomic world 11. constituent part 12. played by a completely different set of rules 13. larger bodies of matter 14. to emerge 15. crisis in physics 16. monumental proportion 17. new phenomenon, phenomena 18. to violate Newton's laws 19. to refine radium 20. magical property of glowing in the dark 21. to come out of nothing 22. conservation of energy 23. to cut electricity, magnetism into finer pieces 24. to have an audacity to say smth. 25. to occur in packets 26. to assume 27. at the fundamental level 28. to have wave-like properties 29. quantum mechanics	30. to be constructed 31. a bowling ball 32. equation governing the electron 33. one of the greatest achievements of the human intellect 34. to peer into an atom itself 35. uncertainty associated with it 36. to make a faithful step 37. waving 38. probability of locating at any given point 39. to give a problem 40. to calculate 41. to dissolve 42. to rematerialize on the other side of brickwall 43. absurd 44. to wind up on Mars 45. to wait longer than lifetime of the Universe 46. to happen all the time 47. electronics 48. modern marvels of electronic age 49. laser beams and microchips 50. ultimately 51. to come down to the fact 52. to be two places at the same time 53. to cause so much problem 54. to break with the quantum theory 55. the God plays dice with the Universe 56. weirdness and built-in uncertainty 57. the best model of the subatomic world

Questions

1. What is a quantum leap? What is it proven to be?
2. What are subatomic particles able to do?
3. What happens in the subatomic world?
4. Who described new rules and quantum theory?
5. When and why did quantum theory emerge? What were new phenomena doing?
6. What did Madam Curie do? What were the properties of a new substance?
7. What did people think at the beginning of XX century?
8. What did Planck say at that time? Why did he say that? What is quantum mechanics?
9. What had been an idea of an atom before?
10. What happened in 1925? What was it for the science? What can we do all of a sudden?
11. What did Max Born do? Why? How did he characterise waving?
12. What problem are the graduate students given? Why is it absurd? What is the probability?
13. What do we call electronics? What fact do all marvels of electronic age come down to?
14. What caused so much problem? What did Einstein finally do? What did he say?
15. What does quantum theory remain to be?

Proper names: Max Plunk, Madam Curie, Max Born

Phonetic exercises:

Flaps

i**t** is proven **t**o be, suba**t**omic, impossibili**t**y, a**t**om, ma**tt**er, se**t** of rules, viola**t**ed, proper**t**y, ou**t** of, electrici**t**y, grea**t**est, par**t**icles, probabili**t**y, la**t**er, ma**d**e a, wha**t** a, loca**t**ing

Glattalisation

comple**t**ely, cu**t** electricity

Omissions

smalles**t** leap, differen**t** set of rules, what **h**e called, greates**t** achievements

The Nature of Light

1. the ancients
2. to ask a fundamental question
3. to be made out of
4. to put smth. in a box, to touch, to shake
5. to be everywhere and nowhere
6. to experience Epiphany of light
7. some of the greatest minds
8. to go back to
9. to make the first definitive study on smth.
10. all the colors of the rainbow
11. to come out of smth.
12. a composite
13. a sum of
14. to recombine
15. ROYGBV
16. particulate
17. corpusculs
18. a stream of light
19. alternative (rival) theory
20. to have wave-like properties
21. surfing, a surfer
22. to ride on an ocean wave
23. to come from another angle
24. to interfere, to give an interference pattern
25. to be wiped out
26. to shine out of the small pinhole
27. to collide
28. to have particle properties
29. to take smth. to the next step
30. the genius of smb.
31. two manifestations of the same thing
32. an elephant, a snake
33. to touch the trunk
34. to be a merger of all qualities
35. to introduce the concept of duality
36. helium-neon gas laser
37. to emit
38. coherent
39. to vibrate in unison
40. double slit
41. to criss cross
42. to create the pattern
43. to disperse
44. photons
45. a simple red dot
46. to take the combined efforts of
47. across centuries
48. to live in the Dark Ages

Questions:

1. What question did the ancients ask? What did they think?
2. Who was one of the first to study the nature of light? What were his experiments?
3. What was the first theory of light?
4. Who created the alternative theory? When?
5. What example does Michio Kaku give? What was the experiment demonstrating wave-like properties of light?
6. What did Einstein say?
7. What association was given concerning light theories?
8. What concept did Einstein introduce?
9. What device shown in the episode demonstrates the nature of light? How much energy does it emit?
10. What happens when light comes to the double slit?
11. What would happen if the waves were nothing but individual particles?
12. What helped us to understand light?

Phonetic exercises

Flaps: fundamen**t**al, wa**t**er, ma**d**e out of, grea**t**est, stu**d**ies, pa**tt**ern, beau**t**iful, proper**t**ies, duali**t**y

Glattals: i**t** was, New**t**on, comes a**t** you, look a**t**

AUDIO PRACTICE
ECOLOGICAL ISSUES
Texts 1-6

Tasks

1. Practice flaps, glottal sounds and words with vowel and consonant omission.
2. Study the questions.
3. Translate the key-words. Practice the pronunciation of the key-words.
4. Make suggestions about the content of the text not listening to it.
5. Listen to texts 1-4 twice and answer the questions after each text.
6. Retell the texts as if you were:
   environmentalist;
   minister of economy;
   manufacturer;
   person living in environmentally problematic area;
   doctor.
7. Make up dialogs between:
   a scientist and a journalist;
   a manufacturer and a person from Green Peace;
   a producer of pollution control equipment and a manufacturer;
   an environmentalist and an ordinary citizen;
   a Minister of Nature Conservation and a journalist.

Text 1. Kinds of pollution (Gene)

Key words

1) to be concerned about;
2) thermal pollution;
3) to burn fuel;
4) to generate heat, to reject heat into;
5) power plant;
6) condenser;
7) cooling tower;
8) greenhouse effect;
9) carbon dioxide;
10) nitrites of oxide;
11) to be injurious to smb;
12) diesel;
13) to emit, emission;
14) exhaust;
15) oil spill;
16) to recover.

Questions

1. Which kinds of pollution does the speaker enumerate?
2. What can cause thermal pollution?
3. What injures people when they breathe?
4. When does oil spill occur? Why is it dangerous? Is it easy to combat the problem of oil spill? Why?

Text 2. Acid rain (Gene)

Key words
1) sulfur, sulfur-bearing fuels, sulfuric acid;
2) pitting;
3) metal enclosures;
4) acid fumes;
5) to inhale;
6) to lie downstream.

Questions
1. What is the cause of acid rain?
2. How can acid rain harm wildlife and people?
3. Does it harm people's welfare and industries?
4. What countries are given as an example of harm from acid rain?

Text 3. Global warming (Gene)

Key words
1) controversial issue;
2) neutral;
3) evidence;
4) glacier;
5) to recede;
6) to melt;
7) large amounts of water;
8) flooding;
9) water level;
10) in a global sense;
11) to affect smb.;
12) the globe;
13) to be localized at region or nation.

Questions
1. What do people think about global warming?
2. What are the reasons of global warming?
3. What are the consequences of global warming?
4. What is the speaker's attitude to the problem of global warming?

Text 4. Green Peace (Gene)

Key words
1) to be aware of, awareness;
2) environmental issues;
3) narrow, narrowly;
4) interaction;
5) suggestions for solutions;
6) to take into account;
7) entire;
8) spectrum/range of smth.;
9) broad picture;
10) to impact the environment.

Questions

1. What is positive in the activity of Green Peace?
2. What is negative?
3. How strong are these organizations at home and abroad?
4. How difficult is the choice of economic wealth and healthy environment?

Phonetic exercises

Exercise 1. *Flaps*
tha**t** is, genera**t**ing, associa**t**ed, wa**t**er, au**t**omobile, due **t**o the gasses, ma**tt**er, comes ou**t** exhaust, is ge**tt**ing to be, pi**tt**ing, me**t**al, loca**t**ed, i**t** is no**t** a problem, beau**t**y, activi**t**y, on the par**t** of people

Exercise 2. *Glottal consonants (differentiate between voiceless implosives, voiced implosives and glottal burst)*

abou**t**, cer**t**ain, a**t**mosphere, hea**t**, emi**t** from, uni**que** kind, plan**t** life, coul**d** cause, recen**t**ly, importantly, tha**t** can lead, ma**ke** people, broa**d** picture

Exercise 3. *Consonant and vowel omissions*
diff**e**r**e**n**t** kin**d**s, p**o**llution, one o**f** them, o**f** power plants, effec**t**s, prob**le**m, an**d** recede, aroun**d** the globe, environmen**t**al issues

Text 5 (Paul)

Key words
1) to be connected with;
2) to throw away;
3) free lunch, to get smth for free;
4) reutilize;
5) to conserve;
6) to degradete.

Questions
1. What meaning of ecological education does Paul see?
2. What basic ecological principles does he name?
3. What will people begin to understand with ecological education?

Text 6 (Douglas)

Key words
1) sincere concern;
2) impact upon environment;
3) to be quick to put laws;
4) to keep emissions from cars;
5) highly centralized organization;
6) preservation of the water supply;
7) cleaningness of the air;
8) to need appropriate standards;
9) significant/insignificant;
10) the amount of industrial waste;
11) to result in health problems;
12) to put pressure;
13) to respond with safe cars;
14) to install limitations.

Questions

1. What is people's attitude to ecological problems in the US?
2. Who contributes into solving ecological problems in the US?
3. What is the primary ecological concern of the US according to Douglas?
4. Does Douglas consider ecological issues significant in Russia? Why? Do you agree? Give for/against examples.
5. How serious is the problem in highly industrialized societies?
6. How active are the people living in such countries? Does the government react positively to that?
7. Is it wise to wait for deep deterioration of ecological problems to appear to take drastic steps?
8. Do you know any evidences of caring about the environment on the global scale?

Phonetic exercises

Exercise 1. *Flaps*
tha**t** aspect, reu**t**ilize, alrea**d**y, me**t**als, tha**t** are, no**t**iced, the Uni**t**ed States, a lo**t** of, au**t**omobiles, coopera**t**ing, wa**t**er quali**t**y, no**t** unusual, socie**t**ies, resul**t** of, inevi**t**ably, try **t**o install

Exercise 2. *Glottal consonants (differentiate between voiceless implosives, voiced implosives and glottal burst)*

tha**t** we face, throughou**t** the worl**d**, can no**t** throw, don'**t** get, goo**d** conditions, no**t** like, qui**ck** to pu**t** laws, which ke**pt**

Exercise 3. *Consonant and vowel omissions*
environmen**t**al, concep**t**s, significan**t** difference, impac**t**, environmen**t**, governmen**t** is quick, an**d** also kep**t** emissions, the amoun**t** of

Vocabulary exercises

Exercise 1. *Insert necessary words from the vocabulary list of the block*
1. Gases automobiles produce are called ... 2. ... are injurious for people when they breathe them. 3. The large amount of water resulting from the melting of glaciers can cause ... 4. The factory has been ... black smoke from its chimneys, which is against the law. 5. John ... deeply and started coughing. 6. Glaciers are melting, the water level in the ocean is increasing – all these ... of global warming cannot be hidden. 7. As the sea ... many beautiful shells were left behind. 8. Snow ... in the sun like sugar – in the tea. 9. They were not ... of the disaster and didn't manage to leave before the flooding. 10. Rescuing can be successfully held only if there is close ... between rescue services. 11. Acid rain is certainly a problem for those areas witch lie ... power plants. 12. Acid rain results from the burning of ... 13. Burning of fuel and generating heat to the atmosphere leads to ... which is extremely dangerous for our planet. 14. I'm neither for nor against, I'm ... 15. Every power plant has ...which reject heat into the air. 16. Oil spills can cause significant damage to the environment as it takes years for nature to ... 17. Health problems of these people are the result of the work of the plant in that area, that's why the authorities are going to ... on its activity. 18. Sustainable use of water resources is of ... importance as it's the way to preserve water supply for further generations. 19. Forest reserve was established by the government to ... woods. 20. Permission to organize picnics in the forest can only help to ... it. 21. I realized pretty soon that there was no such thing as a ..., anyhow you had to pay back. 22. Drying of the lake was not a surprise for him, as James was ... that the deadline to save that lake had already passed. 23. The close ... between environmental service and environmental science contributes to environmental protection.

Exercise 2. *Give synonyms to the underlined words from the vocabulary list of the block*
1. Nitrites of oxide are dangerous for people to breathe in. 2. Automobile engines produce harmful gasses that cause green-house effect. 3. In your report you should take in to consideration all the factors that influence climate variations in this area. 4. I know about the damage that acid rain causes to buildings and metal enclosures. 5. Automobile exhaust is dangerous for people's health.

6. Packs should be produced in such a way that it' ll be possible to utilize them after usage. 7. Universal community is extremely worried about the impact of industries on the environment. 8. The rays of heat are constantly being rejected by the warm earth to the atmosphere. 9. It was some years before the lake could restore after the oil spill. 10. Susan is indifferent about all this environmental stuff. 11. There is every indication that this river suffers from thoughtless human activity. 12. Even a fraction of what's really happening to marine mammals influenced him greatly. 13. Rescue operations were successful because of the coordination of actions of all agencies. 14. Remember, that you'll never in your life get anything for free. 15. The purpose of our environmental movement is to keep endangered species in safety. 16. It was essential to note that the story about deforestation didn't appear in the newspapers. 17. Deterioration of ecological problems will lead to great health problems.

Exercise 3. *Give opposites to the underlined words from the vocabulary list of the block*
1. The government of this country don't care about environmental pollution. 2. Nitrites of oxide are not dangerous for people when they breathe them in. 3. Human activity has no influence on the environment. 4. This organization is too broadly focused on environmental problems but anyway it makes people aware of ecological damage. 5. I'm absolutely uninformed about water pollution in this city. 6. We have some insignificant issues to discuss today. 7. The authorities didn't restrict the activity of a local power plant. 8. The report of a young scholar was devoted to pollution of air in the region he lived in. 9. As a rule the government is rather sluggish in passing laws concerning environmental protection. 10. After watching the clip the committee got just a fraction of what's happening to the national forest. 11. This region is suffering from constant droughts. 12. You failed to take this very important fact into consideration. 13. I know that Steven always collects paper bags and glass. 14. The professor argued that such means of processing toxic wastes didn't lead to health problems.

Exercise 4. *Develop the following statements into the situations of 5-7 sentences using the vocabulary of the block*

1. The problem of environment pollution is not localized just at region or a nation.
2. There are a lot of kinds of pollution.
3. It is impossible to take control of air pollution.
4. Waste disposal is a great problem in modern industry.
5. Acid rains damage forests, buildings, metal enclosures.
6. Global warning is a very controversial issue.
7. Ecological units do a lot of positive things.
8. Ecological education is necessary to help us resolve environmental problems.
9. Attitude to ecological problems is different in different countries.

Discussion: Environment protection

Task: *Express your views on the following issues using the vocabulary of the block*

1. The most dangerous kinds of pollution.
2. Pollution and people’s health.
3. The role of ecological education.
4. Pure environment and economic wealth: the golden middle.
5. Measures to protect the environment at home and abroad.

READING

“Plasma Physics and Fusion Energy” by J. Friedberg

Fusion and World Energy. Introduction

- **Read and translate vocabulary**

1. energy consumption	20. to be subject to the constraint of
2. to be essential	21. energy options
3. to operate industrial facilities	22. to be identified
4. to be likely to get worse	23. to evaluate
5. a steadily increasing demand	24. fusion
6. economically feasible	25. comparison
7. environmentally friendly manner	26. attractive features
8. portfolio of options	27. in terms of
9. world usage	28. damage
10. supply problem	29. to provide
11. evidence	30. an uninterrupted and reliable manner
12. greenhouse gases	31. to become a major contributor
13. to have an observable negative impact	32. to fuel the dreams of researchers
14. to be alleviated by	33. to overcome challenges
15. substantial reserves of coal	34. to be inherent in
16. to generate energy	35. to integrate smth. into competitive power plant
17. primary fossil fuels	36. to allow fusion to fulfill its role
18. to be exhausted	37. to fit into the future energy mix
19. to be a real issue for	

- **Prepare phonetic reading and literary translation of the 3d and 5th passages**
- **Answer the following questions:**

What has been well known for many years?
What is energy essential for?
Are problems with energy situation likely to get better?
Why is there a steadily increasing demand for a new energy production?
What do all projections of future energy consumption conclude?
Why does the supply problem concern environment?
How could the energy supply situation be alleviated?
What is a further complication?
Is there an ideal energy option?
What do comparisons of fusion with the other energy options show?
What are disadvantages of fusion?
What is the final challenge?

- **Make up a summary of the text**

The Existing Energy Options. Background

- **Read and translate the following word-combinations**

1. to fall into	13. to be singled out
2. renewables	14. high versatility
3. to be used towards desired end purpose	15. a detailed breakdown
4. to be utilized	16. energy capacity
5. multitude of ways	17. to be met by a combination of energy
6. applicable	18. geothermal energy
7. efficiency of utilization	19. to be replaced by
8. cost	20. the production of synthetic fuels
9. conservation methods	21. a vital step
10. to be used to the maximal extent	22. to accomplish the mission
11. to solve the problem	23. a long-term solution
12. to apportion smth. to direct applications	24. in the interim

- **Make up 3-4 sentences with the word-combinations.**
- **Make up 7 questions to the text.**
- **Prepare the role retelling.**

Coal

- **Read and translate the following word-combinations**

1. at the current usage rate	15. unavoidable consequence
2. fuel availability	16. to occur
3. the solution for the foreseeable future	17. a steam cycle
4. to become less desirable	18. fuel combustion
5. remotely located power plants	19. generation of carbon dioxide
6. «base load» electricity	20. greenhouse effect
7. lowest-cost producers	21. coal-specific disadvantages
8. to correspond to	22. impurity
9. the efficiency of converting coal to electricity	23. to release fly ash
	24. electrostatic precipitators
10. burning any fossil fuel	25. scrubbers
11. output	26. radioactive isotopes
12. a heat exchanger	27. fractional amounts
13. to imply	28. superior alternatives
14. smokestack	

- **Make up 7 questions to the text**
- **Make up a summary of the text**

Natural Gas

Find the sentences containing the word-combinations

1. to be derived from	13. contributions to the greenhouse effect
2. liquefied natural gas	14. current estimates
3. with respect to	15. to lie within the boundaries of the industrialized nations
4. to burn more cleanly	16. to be consumed
5. far fewer emissions	17. high demand coupled with
6. to be built in smaller units	18. scarce reserves
7. more rapid construction time	19. to store gas
8. a smaller initial investment	20. need for pipelines and high pressure liquid storage tanks
9. desirable financial incentives	21. to be a poor allocation of a valuable natural resource
10. «combined cycle» mode	22. short-term economics
11. to lead to an increased conversion efficiency	23. to dominate the tradeoffs
12. in terms of convenience and cost	

- **Make up 3-4 sentences with the word-combinations.**
- **Make up 7 questions to the text.**
- **Prepare the role retelling.**

Oil

- **Read and translate the following word-combinations**

1. portability	
2. large energy content	20. Bio-conversion
3. impressive feat	21. to be a plausibly efficient replacement for
4. fully loaded fuel tank	22. to use hydrogen in conjunction with fuel cells
5. a negligible fraction	23. water vapor
6. untaxed price	24. to overcome challenges
7. appear to be a bargain	25. much of the gain is canceled
8. in total magnitude	26. at atmospheric pressure
9. crude oil	27. to be compressed
10. to be fraught with political instability	28. to pose a design problem
11. the competition for oil	29. on-board storage
12. limiting supplies	30. to require a costly cryogenic system
13. to decrease the dependency on oil	31. to develop room-temperature compounds
14. to use hybrid vehicles	32. to store and rapidly cycle
15. to raise an initial cost of an automobile	33. to have a mixture of unfavorable problems
16. to be reluctant to follow this path	34. to evolve towards
17. coal tars and oil shale	
18. the end product	
19. non-petroleum fuels	

- **Make up 3-4 sentences with the word-combinations.**
- **Make up 7 questions to the text.**
- **Prepare the role retelling.**

Nuclear power

Vocabulary

1. the fissioning	23. to self-destruct by radioactive decay
2. a source of electricity	24. scrutiny
3. nuclear fuel rods	25. to be dissolved in glass
4. to fit in	26. to be reprocessed
5. harmful emissions	27. nuclear «rubbish»
6. a radiation accident	28. nuclear proliferation
7. a financial disaster	29. to gain access
8. to be released	30. to make a weapon
9. to be designed	31. to be diverted
10. overlapping layers of safety	32. to involve the detection and prevention
11. a huge steel reinforced containment vessel	33. to justify
12. to be licensed	34. surreptitious diversion
13. to be consumed	35. legitimate
14. «spent fuel» rods	36. well-intentioned
15. to be buried	37. ill-conceived
16. non-retrievable repository	38. to follow suit
17. to be chemically extracted	39. to expand
18. to breed	40. to fill the gap
19. to extend the reserves	41. underappreciated
20. to dispose of	42. viable option
21. subtleties	43. stumbling block
22. fission byproducts	44. deregulated market
	45. disincentive

- **Make up 3-4 sentences with the word-combinations.**
- **Make up 7 questions to the text.**
- **Prepare the role retelling.**

Wind power

1. to strike the blades
2. windmill
3. to rotate
4. gear
5. harmful pollutants
6. hidden environmental costs
7. to spin too fast
8. to cause damage
9. excess power
10. a coal furnace
11. city plus suburbs
12. the issue of aesthetics
13. unattractive eyesores
14. mounting towers
15. a topping source of power
16. peak demand
17. fluctuations
18. transmission grid

- **Make up 3-4 sentences with the word-combinations.**
- **Make up 7 questions to the text.**
- **Prepare the role retelling.**

TESTS

Test (Physics, video)

- **Insert the necessary word or word-combination from the list:**

1. The … is one of the great engineering fits.
2. An electric generator in its basic form is … .
3. What did Michael Faraday do? – He was a … with an interest in electricity.
4. The device in the museum looks like … .
5. Without works of Faraday and Maxwell … would not be possible.
6. The second law of thermodynamics studies … of different kinds of energy.
7. Electricity and magnetism are … .
8. Rudolf Clausius coined the word … .
9. Michael Faraday kept … on the experiments.
10. One test is … a thousand experts' opinions.
11. Don't be afraid, electricity won't … inside, you can … on the inside of the bar.
12. This scientist was able to … the process.
13. Faraday's notes proved … for Maxwell.
14. I know that electricity is distributed on … .
15. How many … do we have on the orbit?
16. When you … electric current, magnetic field disappears.
17. How much energy is actually … in the process of moving a car? – About 80 %.
18. You should … to make a fabric.
19. I want to … more about this discovery, that's why I'm going to this museum.
20. … of the Industrial Revolution depended upon energy.

book binder, wasted, turn a loom, a coil of wire between the poles of magnet, put your finger, turn off, satellites, worth, a conducting surface, find out, reverse, penetrate, cryptic notes, entropy, power driven machinery, interrelated, transformations, invaluable, modern communication, a giant birdcage, Hoover dam.

- **Translate into English:**

1. Высота этой дамбы почти 100 метров, но я не знаю, сколько она весит.
2. Как электричество двигается по проводам?
3. Эта гигантская клетка сделана из металла.
4. Вы должны попытаться и сделать (произвести) несколько вспышек молнии.
5. Он заставил поезд двигаться по рельсам.

Test (Магистры)

- **Insert the necessary words from the list:**

1. Unfortunately ... is available in few areas of the world that are ... with political instability.
2. It's absurd! How can you go to sleep on Earth and ... .
3. Most of the known reserves of natural gas do not lie within ... of the industrialized nations.
4. The energy of motion ... making you heavier.
5. Many people in Russia are ... to drive smaller automobiles.
6. He had an ... to say that energy occurs in ... .
7. Many people think that the use of natural gas to produce electricity is a ... of a natural resource.
8. This equation ... enormous amount of energy contained in ... .
9. Many economists predict that the ... for oil will increase because of ... .
10. Einstein finally ... with the quantum theory because it caused so much problem.
11. When you approach light speed ... take place: time ..., space ... .
12. Nowadays costly ... are used for storing many things in different areas.
13. This leads to a more rapid construction time and a smaller ..., both desirable incentives.
14. One of the advantages of hydrogen is that the end product of the process is harmless ... .

15. When some object ... it still possesses enormous amounts of energy.

crude oil, bizarre distortions, stands still, poor allocation, packets, a small quantity of matter, beats slower, competition, boundaries, reluctunt, broke, contracts, hints at, audacity, water vapor, cryogenic systems, initial investment, turns into, wind up on Mars, limiting supplies, fraught

- **Translate into English:**

1. Радий обладает удивительной способностью светиться в темноте, при этом энергия появляется ниоткуда.
2. Хотя этанол является очевидным эффективным заменителем бензина, его производство очень дорого.
3. Это открытие явилось гигантским скачком для науки и многие все еще пытаются переварить его.
4. Покупка бензина оказывается выгодной сделкой даже по существующим высоким ценам.
5. Как можно быть в двух местах одновременно? -- Но с электронами это происходит все время!
6. Транспортировать и хранить природный газ очень дорого, поскольку существует потребность в трубопроводах и емкостях под высоким давлением.
7. В начале XX века в физике наблюдался кризис, т.к многие явления нарушали законы Ньютона.
8. Использование гибридных транспортных средств повышает первоначальную стоимость автомобиля.
9. Природный газ горит чище, чем уголь, производя намного меньше выбросов.
10. Частицы в субатомном мире подчиняются совершенно другим правилам, чем материальные объекты.

Terminal Test (Physics)

- **Insert the necessary word or word-combination from the list:**

1. When environmental concerns are considered, coal becomes ... .
2. A hammer and a feather ... at different rates.
3. Energy is singled out because of its high ... .
4. ... any fossil fuel is a chemical process whose main output is heat.
5. Gravitational force of the Moon causes ... .
6. Ancient Greeks believed that nature obeys ... .
7. The unavoidable generation of carbon dioxide is largely responsible for ... .
8. ... acts on different things alike including apples, Moon and planets.
9. Problems with energy situation are likely ... because of the ecology.
10. This center carries out a microgravity research with the help of ... .
11. How much energy is actually ... of moving train down the rails?
12. Energy is essential for ..., heating houses, lighting.
13. That discovery was ... in science.
14. Cylinders and engine blocks ... and ... in the process of moving a car.
15. Gravitational force is a ... discovery in science.
16. The primary natural resources used to produce energy ... 3 main categories.
17. If you hit a hockey puck it will ... .
18. Newton ... of what is known as classical physics.
19. Ethanol and hydrogen are ... which ultimately may be used to replace gasoline and diesel fuel.
20. The emissions can be reduced by ... .

burning, to get worse, vacuum chamber, established the foundation, fall into, electrostatic scrubbers, less desirable, operating industrial facilities, to keep sliding off across the ice, *versatility, wear out, ebb and flow of Earth's oceans, a turning point, gravitational force, greenhouse effect, hit the ground, lost in the process, a set of laws, corrode, landmark, synthetic fuels*

- **Translate into English**

1. Это вещество можно утилизировать, используя множество способов.
2. Эффективность превращения угля в электричество очень низкая.
3. Когда вы включаете электричество, появляется магнитное поле.
4. Электрогенератор в его базовом виде – это витки провода между полюсами магнита.
5. Парниковые газы имеют очевидное негативное воздействие на окружающую среду.
6. Какая странная сила связывает всю Вселенную и все вещества?

Term Test (Магистры, summer)

- **Insert the necessary word from the list:**

1. Nuclear power has received much attention as a ... of electricity.
2. The worst ... accident in a USA plant occurred at Three Mile Island.
3. It could cause damage to people as they inhale or breathe these acid ... from the rain.
4. When light comes to the double slit waves begin to ... .
5. Nuclear ... concerns the possibility that terrorist groups would gain access to nuclear weapons.
6. It took the ... of 3 scientists to understand the nature of light.
7. Global warming, certainly, is a very ... issue.
8. The resulting ... are buried in a permanent, non-retrievable repository.
9. The ancients asked a fundamental question – what is the world ...?
10. Acid rain results from the burning of ... which go into the air and react.
11. Western nuclear power plants are designed with many ... of safety to provide defense.
12. Radioactive ... have reasonably short half lives, on the order of 30 years or less.
13. It takes years to ... from oil spills.
14. A surfer riding on an ocean wave can be ... by another wave.
15. People are very concerned about ... pollution.
16.

Radiation, recover, «spent fuel» rods, thermal, combined efforts, sulphur bearing fuels, fumes, criss cross, controversial, made out of, wiped out, overlapping layers, fission byproducts, proliferation, source,

- **Translate into English:**

1. Описывая природу света, Эйнштейн ввел концепцию дуализма.
2. Огромный стальной саркофаг вокруг реактора может защитить население в случае происшествия.
3. Появляется все больше свидетельств, что ледники начинают таять и уменьшатся в размерах.
4. Ядерные отходы можно растворить в стекле и хранить там постоянно.
5. Свет имеет как свойства частиц, так и волновые свойства.
6. Ядерные электростанции не производят углекислый газ и другие вредные выбросы.
7. Тепловое загрязнение – это результат сжигания топлива и выработки тепла, которое идет в атмосферу.
8. Отработанное топливо из реактора нельзя использовать напрямую для изготовление оружия.
9. Многие экологические организации не понимают взаимодействие разных систем.
10. Многие ядерные отходы само разрушаются путем радиоактивного распада.

Exams and pass-fail tests

Text 1

History

The word *energy* derives from Greek ἐνέργεια (*energeia*), which appears for the first time in the work Nicomachean Ethics of Aristotle in the 4th century BC. In 1021 AD, the Arabian physicist, Alhazen, in the Book of Optics, held light rays to be streams of minute energy particles, stating that "the smallest parts of light" retain "only properties that can be treated by geometry and verified by experiment" and that "they lack all sensible qualities except energy. In 1121, Al-Khazini, in *The Book of the Balance of Wisdom*, proposed that the gravitational potential energy of a body varies depending on its distance from the centre of the Earth.

The concept of energy emerged out of the idea, which Leibniz defined as the product of the mass of an object and its velocity squared. To account for slowing due to friction, Leibniz claimed that heat consisted of the random motion of the constituent parts of matter — a view shared by Isaac Newton, although it would be more than a century until this was generally accepted. In 1807, Thomas Young was the first to use the term "energy" instead of vis viva, in its modern sense. Gustave-Gaspard Coriolis described "kinetic energy" in 1829 in its modern sense, and in 1853, William Rankine coined the term "potential energy." It was argued for some years whether energy was a substance or merely a physical quantity.

William Thomson (Lord Kelvin) amalgamated all of these laws into the laws of thermodynamics, which aided in the rapid development of explanations of chemical processes using the concept of energy by Rudolf Clausius, Josiah Willard Gibbs, and Walther Nernst. It also led to a mathematical formulation of the concept of entropy by Clausius and to the introduction of laws of radiant energy by Jožef Stefan.

During a 1961 lecture for undergraduate students at the California Institute of Technology, Richard Feynman, a celebrated physics teacher and Nobel Laureate, said this about the concept of energy:

There is a fact, or if you wish, a law, governing natural phenomena that are known to date. There is no known exception to this law; it is exact, so far we know. The law is called conservation of energy; it states that there is a certain quantity, which we call energy that does not change in manifold changes which nature undergoes. That is a most abstract idea, because it is a mathematical principle; it says that there is a numerical quantity, which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number, and when we finish watching nature go through her tricks and calculate the number again, it is the same.

—*The Feynman Lectures on Physics*

Since 1918 it has been known that the law of conservation of energy is the direct mathematical consequence of the translational symmetry of the quantity conjugate to energy, namely time. That is, energy is conserved because the laws of physics do not distinguish between different moments of time.

Text 2

Energy in various contexts since the beginning of the universe

The concept of energy is widespread in all sciences.

In biology, energy is an attribute of all biological systems from the biosphere to the smallest living organism. Within an organism it is responsible for growth and development of a biological cell. Energy is thus often said to be stored by cells in the structures of molecules of substances such as carbohydrates (including sugars) and lipids, which release energy when reacted with oxygen. In human terms, the human equivalent (H-e) (Human energy conversion) The human equivalent energy indicates, for a given amount of energy expenditure, the relative quantity of energy needed for human metabolism, assuming an average human energy expenditure of 12,500kJ per day and a basal metabolic rate of 80 watts. For example, if our bodies run (on average) at 80 watts, then a light bulb running at 100 watts is running at 1.25 human equivalents (100 ÷ 80) i.e. 1.25 H-e. For a difficult task of only a few seconds' duration, a person can put out thousands of watts—many times the 746 watts in one official horsepower. For tasks lasting a few minutes, a fit human can generate perhaps 1,000 watts. For an activity that must be sustained for an hour, output drops to around 300; for an activity kept up all day, 150 watts is about the maximum. The human equivalent assists understanding of energy flows in physical and biological systems by expressing energy units in human terms: it provides a “feel” for the use of a given amount of energy

In geology, continental drift, mountain ranges, volcanoes, and earthquakes are phenomena that can be explained in terms of energy transformations in the Earth's interior. While meteorological phenomena like wind, rain, hail, snow, lightning, tornadoes and hurricanes, are all a result of energy transformations brought about by solar energy on the atmosphere of the planet Earth.

In cosmology and astronomy the phenomena of stars, nova, supernova, quasars and gamma ray bursts are the universe's highest-output energy transformations of matter. All stellar phenomena (including solar activity) are driven by various kinds of energy transformations. Energy in such transformations is either from gravitational collapse of matter (usually molecular hydrogen) into various classes of astronomical objects (stars, black holes, etc.), or from nuclear fusion (of lighter elements, primarily hydrogen).

Energy transformations in the universe over time are characterized by various kinds of potential energy which has been available since the Big Bang, later being "released" (transformed to more active types of energy such as kinetic or radiant energy), when a triggering mechanism is available.

Familiar examples of such processes include nuclear decay, in which energy is released which was originally "stored" in heavy isotopes (such as uranium and thorium), by nucleosynthesis, a process which ultimately uses the gravitational potential energy released from the gravitational collapse of supernovae, to store energy in the creation of these heavy elements before they were incorporated into the solar system and the Earth. This energy is triggered and released in nuclear fission bombs. In a slower process, heat from nuclear decay of these atoms in the core of the Earth releases heat, which in turn may lift mountains. This slow lifting represents a kind of gravitational potential energy storage of the heat energy, which may be released to active kinetic energy in landslides, after a triggering event.

Text 3

Regarding applications of the concept of energy

Energy is subject to a strict global conservation law; that is, whenever one measures (or calculates) the total energy of a system of particles whose interactions do not depend explicitly on time, it is found that the total energy of the system always remains constant.

61) The total energy of a system can be subdivided and classified in various ways. For example, it is sometimes convenient to distinguish potential energy from kinetic energy. It may also be convenient to distinguish gravitational energy, electric energy, thermal energy, and other forms. These classifications overlap; for instance thermal energy usually consists partly of kinetic and partly of potential energy.

62) The *transfer* of energy can take various forms; familiar examples include work, heat flow, and advection.

63) The word "energy" is also used outside of physics in many ways, which can lead to ambiguity and inconsistency. The vernacular terminology is not consistent with technical terminology. For example, the important public-service announcement, "Please conserve energy" uses vernacular notions of "conservation" and "energy" which make sense in their own context but are utterly incompatible with the technical notions of "conservation" and "energy" (such as are used in the law of conservation of energy).

Energy transfer

Because energy is strictly conserved and is also locally conserved (wherever it can be defined), it is important to remember that by definition of energy the transfer of energy between the "system" and adjacent regions is work. A familiar example is mechanical work. In simple cases this is written as:

$$\Delta E = W \qquad (1)$$

if there are no other energy-transfer processes involved. Here E is the amount of energy transferred, and W represents the work done on the system.

More generally, the energy transfer can be split into two categories:

$$\Delta E = W + Q \qquad (2)$$

where Q represents the heat flow into the system.

There are other ways in which an open system can gain or lose energy. In chemical systems, energy can be added to a system by means of adding substances with different chemical potentials, which potentials are then extracted (both of these process are illustrated by fueling an auto, a system which gains in energy thereby, without addition of either work or heat). Winding a clock would be adding energy to a mechanical system. These terms may be added to the above equation, or they can generally be subsumed into a quantity called "energy addition term E" which refers to *any* type of energy carried over the surface of a control volume or system volume. Examples may be seen above, and many others can be imagined (for example, the kinetic energy of a stream of particles entering a system, or energy from a laser beam adds to system energy, without either being either work-done or heat-added, in the classic senses).

Text 4

Energy and the laws of motion

In classical mechanics, energy is a conceptually and mathematically useful property since it is a conserved quantity.

The Hamiltonian

The total energy of a system is sometimes called the Hamiltonian, after William Rowan Hamilton. The classical equations of motion can be written in terms of the Hamiltonian, even for highly complex or abstract systems. These classical equations have remarkably direct analogs in nonrelativistic quantum mechanics.

The Lagrangian

Another energy-related concept is called the Lagrangian, after Joseph Louis Lagrange. This is even more fundamental than the Hamiltonian, and can be used to derive the equations of motion. It was invented in the context of classical mechanics, but is generally useful in modern physics. The Lagrangian is defined as the kinetic energy *minus* the potential energy.

Usually, the Lagrange formalism is mathematically more convenient than the Hamiltonian for non-conservative systems (like systems with friction).

Energy and thermodynamics

Internal energy

Internal energy – the sum of all microscopic forms of energy of a system. It is related to the molecular structure and the degree of molecular activity and may be viewed as the sum of kinetic and potential energies of the molecules; it comprises the following types of energy:[15]

Type	Composition of internal energy (U)
Sensible energy	the portion of the internal energy of a system associated with kinetic energies (molecular translation, rotation, and vibration; electron translation and spin; and nuclear spin) of the molecules.
Latent energy	the internal energy associated with the phase of a system.
Chemical energy	the internal energy associated with the different kinds of aggregation of atoms in matter.
Nuclear energy	the tremendous amount of energy associated with the strong bonds within the nucleus of the atom itself.
Energy interactions	those types of energies not stored in the system (e.g. heat transfer, mass transfer, and work), but which are recognized at the system boundary as they cross it, which represent gains or losses by a system during a process.
Thermal energy	the sum of sensible and latent forms of internal energy.

Text 5

Equipartition of energy

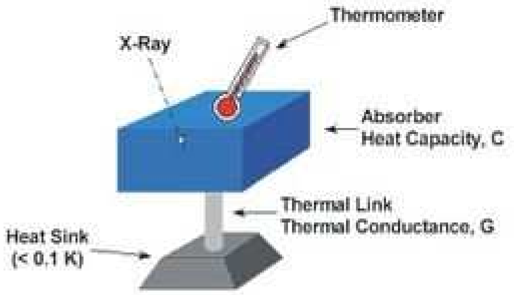
The energy of a mechanical harmonic oscillator (a mass on a spring) is alternatively kinetic and potential. At two points in the oscillation cycle it is entirely kinetic, and alternatively at two other points it is entirely potential. Over the whole cycle, or over many cycles net energy is thus equally split between kinetic and potential. This is called equipartition principle - total energy of a system with many degrees of freedom is equally split among all available degrees of freedom.
This principle is vitally important to understanding the behavior of a quantity closely related to energy, called entropy. Entropy is a measure of evenness of a distribution of energy between parts of a system. When an isolated system is given more degrees of freedom (= is given new available energy states which are the same as existing states), then total energy spreads over **all** available degrees equally without distinction between "new" and "old" degrees. This mathematical result is called the second law of thermodynamics.

Oscillators, phonons, and photons

In an ensemble (connected collection) of unsynchronized oscillators, the average energy is spread equally between kinetic and potential types.
In a solid, thermal energy (often referred to loosely as heat content) can be accurately described by an ensemble of thermal phonons that act as mechanical oscillators. In this model, thermal energy is equally kinetic and potential.
In an ideal gas, the interaction potential between particles is essentially the delta function which stores no energy: thus, all of the thermal energy is kinetic.
Because an electric oscillator (LC circuit) is analogous to a mechanical oscillator, its energy must be, on average, equally kinetic and potential. It is entirely arbitrary whether the magnetic energy is considered kinetic and the electric energy considered potential, or vice versa. That is, either the inductor is analogous to the mass while the capacitor is analogous to the spring, or vice versa.
1. By extension of the previous line of thought, in free space the electromagnetic field can be considered an ensemble of oscillators, meaning that radiation energy can be considered equally potential and kinetic. This model is useful, for example, when the electromagnetic Lagrangian is of primary interest and is interpreted in terms of potential and kinetic energy.
2. On the other hand, in the key equation $m^2c^4 = E^2 - p^2c^2$, the contribution mc^2 is called the rest energy, and all other contributions to the energy are called kinetic energy. For a particle that has mass, this implies that the kinetic energy is $0.5p^2 / m$ at speeds much smaller than *c*, as can be proved by writing $E = mc^2 \sqrt{(1 + p^2m^{-2}c^{-2})}$ and expanding the square root to lowest order. By this line of reasoning, the energy of a photon is entirely kinetic, because the photon is massless and has no rest energy. This expression is useful, for example, when the energy-versus-momentum relationship is of primary interest.
The two analyses are entirely consistent. The electric and magnetic degrees of freedom in item 1 are *transverse* to the direction of motion, while the speed in item 2 is *along* the direction of motion. For non-relativistic particles these two notions of potential versus kinetic energy are numerically equal, so the ambiguity is harmless, but not so for relativistic particles.

Text 6

Measurement



A Calorimeter - An instrument used by physicists to measure energy

There is no absolute measure of energy, because energy is defined as the work that one system does (or can do) on another. Thus, only the transition of a system from one state into another can be defined and thus measured.

Methods

The methods for the measurement of energy often deploy methods for the measurement of still more fundamental concepts of science, namely mass, distance, radiation, temperature, time, electric charge and electric current.

Conventionally the technique most often employed is calorimetry, a thermodynamic technique that relies on the measurement of temperature using a thermometer or of intensity of radiation using a bolometer.

Units

Throughout the history of science, energy has been expressed in several different units such as ergs and calories. At present, the accepted unit of measurement for energy is the SI unit of energy, the joule. In addition to the joule, other units of energy include the kilowatt hour (kWh) and the British thermal unit (Btu). These are both larger units of energy. One kWh is equivalent to exactly 3.6 million joules, and one Btu is equivalent to about 1055 joules.

Forms of energy

Heat, a form of energy, is partly potential energy and partly kinetic energy.

Classical mechanics distinguishes between potential energy, which is a function of the position of an object, and kinetic energy, which is a function of its movement. Both position and movement are relative to a frame of reference, which must be specified: this is often (and originally) an arbitrary fixed point on the surface of the Earth, the *terrestrial* frame of reference. It has been attempted to categorize *all* forms of energy as either kinetic or potential: this is not incorrect, but neither is it clear that it is a real simplification, as Feynman points out:

These notions of potential and kinetic energy depend on a notion of length scale. For example, one can speak of *macroscopic* potential and kinetic energy, which do not include thermal potential and kinetic energy. Also what is called chemical potential energy (below) is a macroscopic notion, and closer examination shows that it is really the sum of the potential *and kinetic* energy on the atomic and subatomic scale. Similar remarks apply to nuclear "potential" energy and most other forms of energy. This dependence on length scale is non-problematic if the various length scales are decoupled, as is often the case ... but confusion can arise when different length scales are coupled, for instance when friction converts macroscopic work into microscopic thermal energy.

Text 7

Mechanical energy

Mechanical energy manifest in many forms, but can be broadly classified into elastic potential energy and kinetic energy. However the term potential energy is a very general term, because it exists in all force fields, such as gravitation, electrostatic and magnetic fields. Potential energy refers to the energy any object gets due to its position in a force field.

Potential energy, symbols E_p, V or Φ, is defined as the work done *against a given force* (= work of *given force* with minus sign) in changing the position of an object with respect to a reference position (often taken to be infinite separation). If **F** is the force and **s** is the displacement,

with the dot representing the scalar product of the two vectors.

The name "potential" energy originally signified the idea that the energy could readily be transferred as work—at least in an idealized system (reversible process, see below). This is not completely true for any real system, but is often a reasonable first approximation in classical mechanics.

The general equation above can be simplified in a number of common cases, notably when dealing with gravity or with elastic forces.

Elastic potential energy

As a ball falls freely under the influence of gravity, it accelerates downward, its initial potential energy converting into kinetic energy. On impact with a hard surface the ball deforms, converting the kinetic energy into elastic potential energy. As the ball springs back, the energy converts back firstly to kinetic energy and then as the ball re-gains height into potential energy. Energy conversion to heat due to inelastic deformation and air resistance cause each successive bounce to be lower than the last.

Main article: Elastic potential energy

Elastic potential energy is defined as a work needed to compress (or expand) a spring. The force, **F**, in a spring or any other system which obeys Hooke's law is proportional to the extension or compression, **x**,

$$F = -kx$$

where k is the force constant of the particular spring (or system). In this case, the calculated work becomes

only when k is constant. Hooke's law is a good approximation for behaviour of chemical bonds under normal conditions, i.e. when they are not being broken or formed.

Kinetic energy

Main article: Kinetic energy

Kinetic energy, symbols E_k, T or K, is the work required to accelerate an object to a given speed. Indeed, calculating this work one easily obtains the following:

At speeds approaching the speed of light, c, this work must be calculated using Lorentz transformations, which results in the following:

This equation reduces to the one above it, at small (compared to **c**) speed. A mathematical by-product of this work (which is immediately seen in the last equation) is that even at rest a mass has the amount of energy equal to:

$$E_{rest} = mc^2$$

This energy is thus called rest mass energy.

Text 8

Surface energy

If there is any kind of tension in a surface, such as a stretched sheet of rubber or material interfaces, it is possible to define **surface energy**. In particular, any meeting of dissimilar materials that don't mix will result in some kind of surface tension, if there is freedom for the surfaces to move then, as seen in capillary surfaces for example, the minimum energy will as usual be sought.

A minimal surface, for example, represents the smallest possible energy that a surface can have if its energy is proportional to the area of the surface. For this reason, (open) soap films of small size are minimal surfaces (small size reduces gravity effects, and openness prevents pressure from building up. Note that a bubble is a minimum energy surface but not a minimal surface by definition).

Sound energy

Sound is a form of mechanical vibration, which propagates through any mechanical medium.

Gravitational energy

Main article: Gravitational potential energy

The gravitational force near the Earth's surface varies very little with the height, h, and is equal to the mass, m, multiplied by the gravitational acceleration, $g = 9.81$ m/s². In these cases, the gravitational potential energy is given by

$$E_{p,g} = mgh$$

A more general expression for the potential energy due to Newtonian gravitation between two bodies of masses m_1 and m_2, useful in astronomy, is

,

where r is the separation between the two bodies and G is the gravitational constant, $6.6742(10)\times10^{-11}$ $m^3kg^{-1}s^{-2}$.[18] In this case, the reference point is the infinite separation of the two bodies.

Thermal energy

Thermal energy (of some media - gas, plasma, solid, etc) is the energy associated with the microscopical random motion of particles constituting the media. For example, in case of monoatomic gas it is just a kinetic energy of motion of atoms of gas as measured in the reference frame of the center of mass of gas. In case of many-atomic gas rotational and vibrational energy is involved. In the case of liquids and solids there is also potential energy (of interaction of atoms) involved, and so on.

A heat is defined as a transfer (flow) of thermal energy across certain boundary (for example, from a hot body to cold via the area of their contact. A practical definition for small transfers of heat is

where C_v is the heat capacity of the system. This definition will fail if the system undergoes a phase transition—e.g. if ice is melting to water—as in these cases the system can absorb heat without increasing its temperature. In more complex systems, it is preferable to use the concept of internal energy rather than that of thermal energy (see Chemical energy below).

Despite the theoretical problems, the above definition is useful in the experimental measurement of energy changes. In a wide variety of situations, it is possible to use the energy released by a system to raise the temperature of another object, e.g. a bath of water. It is also possible to measure the amount of electric energy required to raise the temperature of the object by the same amount. The calorie was originally defined as the amount of energy required to raise the temperature of one gram of water by 1 °C (approximately 4.1855 J, although the definition later changed), and the British thermal unit was defined as the energy required to heat one pound of water by 1 °F (later fixed as 1055.06 J).

Examples of the interconversion of energy	
Electric energy is converted	
into	**by**
Mechanical energy	Electric motor
Thermal energy	Resistor
Electric energy	Transformer
Electromagnetic radiation	Light-emitting diode
Chemical energy	Electrolysis
Nuclear energy	Synchrotron

Electric energy

Electrostatic energy

The electric potential energy of given configuration of charges is defined as the work which must be done against the Coulomb force to rearrange charges from infinite separation to this configuration (or the work done by the Coulomb force separating the charges from this configuration to infinity). For two point-like charges Q_1 and Q_2 at a distance r this work, and hence electric potential energy is equal to:

where ε_0 is the electric constant of a vacuum, $10^7/4\pi c_0^2$ or $8.854188\ldots\times10^{-12}$ F/m.[18] If the charge is accumulated in a capacitor (of capacitance C), the reference configuration is usually selected not to be infinite separation of charges, but vice versa - charges at an extremely close proximity to each other (so there is zero net charge on each plate of a capacitor). The justification for this choice is purely practical - it is easier to measure both voltage difference and magnitude of charges on a capacitor plates not versus infinite separation of charges but rather versus discharged capacitor where charges return to close proximity to each other (electrons and ions recombine making the plates neutral). In this case the work and thus the electric potential energy becomes

Electricity energy

If an electric current passes through a resistor, electric energy is converted to heat; if the current passes through an electric appliance, some of the electric energy will be converted into other forms of energy (although some will always be lost as heat). The amount of electric energy due to an electric current can be expressed in a number of different ways:

where U is the electric potential difference (in volts), Q is the charge (in coulombs), I is the current (in amperes), t is the time for which the current flows (in seconds), P is the power (in watts) and R is the electric resistance (in ohms). The last of these expressions is important in the practical measurement of energy, as potential difference, resistance and time can all be measured with considerable accuracy.

Examples of the interconversion of energy	
Electromagnetic radiation is converted	
into	**by**
Mechanical energy	Solar sail
Thermal energy	Solar collector
Electric energy	Solar cell
Electromagnetic radiation	Non-linear optics
Chemical energy	Photosynthesis
Nuclear energy	Mössbauer spectroscopy

Magnetic energy

There is no fundamental difference between magnetic energy and electric energy: the two phenomena are related by Maxwell's equations. The potential energy of a magnet of magnetic moment **m** in a magnetic field **B** is defined as the work of magnetic force (actually of magnetic torque) on re-alignment of the vector of the magnetic dipole moment, and is equal:

while the energy stored in a inductor (of inductance L) when current I is passing via it is

This second expression forms the basis for superconducting magnetic energy storage.

Electromagnetic Energy

Calculating work needed to create an electric or magnetic field in unit volume (say, in a capacitor or an inductor) results in the electric and magnetic fields energy densities: in SI units.

Electromagnetic radiation, such as microwaves, visible light or gamma rays, represents a flow of electromagnetic energy. Applying the above expressions to magnetic and electric components of electromagnetic field both the volumetric density and the flow of energy in e/m field can be calculated. The resulting Poynting vector, which is expressed as

in SI units, gives the density of the flow of energy and its direction.

The energy of electromagnetic radiation is quantized (has discrete energy levels). The spacing between these levels is equal to

$$E = h\nu$$

where h is the Planck constant, $6.6260693(11)\times10^{-34}$ Js,[18] and v is the frequency of the radiation. This quantity of electromagnetic energy is usually called a photon. The photons which make up visible light have energies of 270–520 yJ, equivalent to 160–310 kJ/mol, the strength of weaker chemical bonds.

Chemical energy

Main article: Chemical thermodynamics

Chemical energy is the energy due to associations of atoms in molecules and various other kinds of aggregates of matter. It may be defined as a work done by electric forces during re-arrangement of mutual positions of electric charges, electrons and protons, in the process of aggregation. So, basically it is electrostatic potential energy of electric charges. If the chemical energy of a system decreases during a chemical reaction, the difference is transferred to the surroundings in some form (often heat or light); on the other hand if the chemical energy of a system increases as a result of a chemical reaction - the difference then is supplied by the surroundings (usually again in form of heat or light). For example,

when two hydrogen atoms react to form a dihydrogen molecule, the chemical energy *decreases* by 724 zJ (the bond energy of the H–H bond);

when the electron is completely removed from a hydrogen atom, forming a hydrogen ion (in the gas phase), the chemical energy *increases* by 2.18 aJ (the ionization energy of hydrogen).

Examples of the interconversion of energy

Chemical energy is converted into	**by**
Mechanical energy	Muscle
Thermal energy	Fire
Electric energy	Fuel cell
Electromagnetic radiation	Glowworms
Chemical energy	Chemical reaction

It is common to quote the changes in chemical energy for one mole of the substance in question: typical values for the change in molar chemical energy during a chemical reaction range from tens to hundreds of kilojoules per mole.

The chemical energy as defined above is also referred to by chemists as the internal energy, U: technically, this is measured by keeping the volume of the system constant. However, most practical chemistry is performed at constant pressure and, if the volume changes during the reaction (e.g. a gas is given off), a correction must be applied to take account of the work done by or on the atmosphere to obtain the enthalpy, H:

$$\Delta H = \Delta U + p\Delta V$$

A second correction, for the change in entropy, S, must also be performed to determine whether a chemical reaction will take place or not, giving the Gibbs free energy, G:

$$\Delta G = \Delta H - T\Delta S$$

These corrections are sometimes negligible, but often not (especially in reactions involving gases).

Since the industrial revolution, the burning of coal, oil, natural gas or products derived from them has been a socially significant transformation of chemical energy into other forms of energy. the energy "consumption" (one should really speak of "energy transformation") of a society or country is often quoted in reference to the average energy released by the combustion of these fossil fuels:

1 tonne of coal equivalent (TCE) = 29.3076 GJ = 8,141 kilowatt hour

1 tonne of oil equivalent (TOE) = 41.868 GJ = 11,630 kilowatt hour

On the same basis, a tank-full of gasoline (45 litres, 12 gallons) is equivalent to about 1.6 GJ of chemical energy. Another chemically-based unit of measurement for energy is the "tonne of TNT", taken as 4.184 GJ. Hence, burning a tonne of oil releases about ten times as much energy as the explosion of one tonne of TNT: fortunately, the energy is usually released in a slower, more controlled manner.

Simple examples of storage of chemical energy are batteries and food. When food is digested and metabolized (often with oxygen), chemical energy is released, which can in turn be transformed into heat, or by muscles into kinetic energy.

Nuclear energy

Main article: Nuclear binding energy

Nuclear potential energy, along with electric potential energy, provides the energy released from nuclear fission and nuclear fusion processes. The result of both these processes are nuclei in which the more-optimal size of the nucleus allows the nuclear force (which is opposed by the electromagnetic force) to bind nuclear particles more tightly together than before the reaction. The Weak nuclear force (different from the strong force) provides the potential energy for certain kinds of radioactive decay, such as beta decay.

The energy released in nuclear processes is so large that the relativistic change in mass (after the energy has been removed) can be as much as several parts per thousand.

Examples of the interconversion of energy

Nuclear binding energy is converted into	**by**
Mechanical energy	Alpha radiation
Thermal energy	Sun
Electrical energy	Beta radiation
Electromagnetic radiation	Gamma radiation
Chemical energy	Radioactive decay
Nuclear energy	Nuclear isomerism

Nuclear particles (nucleons) like protons and neutrons are *not* destroyed (law of conservation of baryon number) in fission and fusion processes. A few lighter particles may be created or destroyed (example: beta minus and beta plus decay, or electron capture decay), but these minor processes are not important to the immediate energy release in fission and fusion. Rather, fission and fusion release energy when collections of baryons become more tightly bound, and it is the energy associated with a fraction of the mass of the nucleons (but not the whole particles) which appears as the heat and electromagnetic radiation generated by nuclear reactions. This heat and radiation retains the "missing" mass, but the mass is missing only because it escapes in the form of heat and light, which retain the mass and conduct it out of the system where it is not measured.

The energy from the Sun, also called solar energy, is an example of this form of energy conversion. In the Sun, the process of hydrogen fusion converts about 4 million metric tons of solar matter per second into light, which is radiated into space, but during this process, the number of total protons and neutrons in the sun does not change. In this system, the light itself retains the inertial equivalent of this mass, and indeed the mass itself (as a system), which represents 4 million tons per second of electromagnetic radiation, moving into space. Each of the helium nuclei which are formed in the process are less massive than the four protons from they were formed, but (to a good approximation), no particles or atoms are destroyed in the process of turning the sun's nuclear potential energy into light.

Transformations of energy

Main article: Energy conversion

One form of energy can often be readily transformed into another with the help of a device- for instance, a battery, from chemical energy to electric energy; a dam: gravitational potential energy to kinetic energy of moving water (and the blades of a turbine) and ultimately to electric energy through an electric generator. Similarly, in the case of a chemical explosion, chemical potential energy is transformed to kinetic energy and thermal energy in a very short time. Yet another example is that of a pendulum. At its highest points the kinetic energy is zero and the gravitational potential energy is at maximum. At its lowest point the kinetic energy is at maximum and is equal to the decrease of potential energy. If one (unrealistically) assumes that there is no friction, the conversion of energy between these processes is perfect, and the pendulum will continue swinging forever.

Energy gives rise to weight and is equivalent to matter and vice versa. The formula $E = mc^2$, derived by Albert Einstein (1905) quantifies the relationship between mass and rest energy within the concept of special relativity. In different theoretical frameworks, similar formulas were derived by J. J. Thomson (1881), Henri Poincaré (1900), Friedrich Hasenöhrl (1904) and others (see Mass-energy equivalence#History for further information). Since c^2 is extremely large relative to ordinary human scales, the conversion of ordinary amount of mass (say, 1 kg) to other forms of energy can liberate tremendous amounts of energy ($\sim 9x10^{16}$ joules), as can be seen in nuclear reactors and nuclear weapons. Conversely, the mass equivalent of a unit of energy is minuscule, which is why a loss of energy from most systems is difficult to measure by weight, unless the energy loss is very large. Examples of energy transformation into matter (particles) are found in

high energy nuclear physics.
In nature, transformations of energy can be fundamentally classed into two kinds: those that are thermodynamically reversible, and those that are thermodynamically irreversible. A reversible process in thermodynamics is one in which no energy is dissipated (spread) into empty energy states available in a volume, from which it cannot be recovered into more concentrated forms (fewer quantum states), without degradation of even more energy. A reversible process is one in which this sort of dissipation does not happen. For example, conversion of energy from one type of potential field to another, is reversible, as in the pendulum system described above. In processes where heat is generated, however, quantum states of lower energy, present as possible exitations in fields between atoms, act as a reservoir for part of the energy, from which it cannot be recovered, in order to be converted with 100% efficiency into other forms of energy. In this case, the energy must partly stay as heat, and cannot be completely recovered as usable energy, except at the price of an increase in some other kind of heat-like increase in disorder in quantum states, in the universe (such as an expansion of matter, or a randomization in a crystal).
As the universe evolves in time, more and more of its energy becomes trapped in irreversible states (i.e., as heat or other kinds of increases in disorder). This has been referred to as the inevitable thermodynamic heat death of the universe. In this heat death the energy of the universe does not change, but the fraction of energy which is available to do produce work through a heat engine, or be transformed to other usable forms of energy (through the use of generators attached to heat engines), grows less and less.

Law of conservation of energy

Main article: Conservation of energy
Energy is subject to the *law of conservation of energy*. According to this law, energy can neither be created (produced) nor destroyed by itself. It can only be transformed.
Most kinds of energy (with gravitational energy being a notable exception)[19] are also subject to strict local conservation laws, as well. In this case, energy can only be exchanged between adjacent regions of space, and all observers agree as to the volumetric density of energy in any given space. There is also a global law of conservation of energy, stating that the total energy of the universe cannot change; this is a corollary of the local law, but not vice versa.[7][12] Conservation of energy is the mathematical consequence of translational symmetry of time (that is, the indistinguishability of time intervals taken at different time)[20] - see Noether's theorem.
According to energy conservation law the total inflow of energy into a system must equal the total outflow of energy from the system, plus the change in the energy contained within the system.
This law is a fundamental principle of physics. It follows from the translational symmetry of time, a property of most phenomena below the cosmic scale that makes them independent of their locations on the time coordinate. Put differently, yesterday, today, and tomorrow are physically indistinguishable.
This is because energy is the quantity which is canonical conjugate to time. This mathematical entanglement of energy and time also results in the uncertainty principle - it is impossible to define the exact amount of energy during any definite time interval. The uncertainty principle should not be confused with energy conservation - rather it provides mathematical limits to which energy can in principle be defined and measured.
In quantum mechanics energy is expressed using the Hamiltonian operator. On any time scales, the uncertainty in the energy is by which is similar in form to the Heisenberg uncertainty principle (but not really mathematically equivalent thereto, since H and t are not dynamically conjugate variables, neither in classical nor in quantum mechanics).
In particle physics, this inequality permits a qualitative understanding of virtual particles which carry momentum, exchange by which and with real particles, is responsible for the creation of all known fundamental forces (more accurately known as fundamental interactions). Virtual photons (which are simply lowest quantum mechanical energy state of photons) are also responsible for

electrostatic interaction between electric charges (which results in Coulomb law), for spontaneous radiative decay of exited atomic and nuclear states, for the Casimir force, for van der Waals bond forces and some other observable phenomena.

Energy and life

Basic overview of energy and human life.

Any living organism relies on an external source of energy—radiation from the Sun in the case of green plants; chemical energy in some form in the case of animals—to be able to grow and reproduce. The daily 1500–2000 Calories (6–8 MJ) recommended for a human adult are taken as a combination of oxygen and food molecules, the latter mostly carbohydrates and fats, of which glucose ($C_6H_{12}O_6$) and stearin ($C_{57}H_{110}O_6$) are convenient examples. The food molecules are oxidised to carbon dioxide and water in the mitochondria

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

$$C_{57}H_{110}O_6 + 81.5O_2 \rightarrow 57CO_2 + 55H_2O$$

and some of the energy is used to convert ADP into ATP

$$ADP + HPO_4^{2-} \rightarrow ATP + H_2O$$

The rest of the chemical energy in the carbohydrate or fat is converted into heat: the ATP is used as a sort of "energy currency", and some of the chemical energy it contains when split and reacted with water, is used for other metabolism (at each stage of a metabolic pathway, some chemical energy is converted into heat). Only a tiny fraction of the original chemical energy is used for work:[21]

gain in kinetic energy of a sprinter during a 100 m race: 4 kJ

gain in gravitational potential energy of a 150 kg weight lifted through 2 metres: 3kJ

Daily food intake of a normal adult: 6–8 MJ

It would appear that living organisms are remarkably inefficient (in the physical sense) in their use of the energy they receive (chemical energy or radiation), and it is true that most real machines manage higher efficiencies. However, in growing organisms the energy that is converted to heat serves a vital purpose, as it allows the organism tissue to be highly ordered with regard to the molecules it is built from. The second law of thermodynamics states that energy (and matter) tends to become more evenly spread out across the universe: to concentrate energy (or matter) in one specific place, it is necessary to spread out a greater amount of energy (as heat) across the remainder of the universe ("the surroundings").[22] Simpler organisms can achieve higher energy efficiencies than more complex ones, but the complex organisms can occupy ecological niches that are not available to their simpler brethren. The conversion of a portion of the chemical energy to heat at each step in a metabolic pathway is the physical reason behind the pyramid of biomass observed in ecology: to take just the first step in the food chain, of the estimated 124.7 Pg/a of carbon that is fixed by photosynthesis, 64.3 Pg/a (52%) are used for the metabolism of green plants,[23] i.e. reconverted into carbon dioxide and heat.

Energy and Information Society

Modern society continues to rely largely on fossil fuels to preserve economic growth and today's standard of living. However, for the first time, physical limits of the Earth are met in our encounter with finite resources of oil and natural gas and its impact of greenhouse gas emissions onto the global climate. Never before has accurate accounting of our energy dependency been more pertinent to developing public policies for a sustainable development of our society, both in the industrial world and the emerging economies. At present, much emphasis is put on the introduction of a worldwide cap-and-trade system, to limit global emissions in greenhouse gases by balancing regional differences on a financial basis. In the near future, society may be permeated at all levels with information systems for direct feedback on energy usage, as fossil fuels continue to be used privately and for manufacturing and transportation services. Information in today's society, focused on knowledge, news and entertainment, is expected to extend to energy usage in real-time. A collective medium for energy information may arise, serving to balance our individual and global energy dependence on fossil fuels. Yet, this development is not without restrictions, notably privacy issues. Recently, the Dutch Senate rejected a proposed law for mandatory national introduction of smart metering, in part, on the basis of privacy concerns.

Card 1

1. Modern society continues to rely largely on fossil fuels to preserve economic growth and today's standard of living.
2. In growing organisms the energy that is converted to heat serves a vital purpose.
3. Any living organism relies on an external source of energy—radiation from the Sun in the case of green plants; chemical energy in some form in the case of animals—to be able to grow and reproduce.
4. According to energy conservation law the total inflow of energy into a system must equal the total outflow of energy from the system, plus the change in the energy contained within the system.

Card 2

1. Most kinds of energy (with gravitational energy being a notable exception) are subject to strict local conservation laws.
2. One form of energy can often be readily transformed into another with the help of a device- for instance, a battery, from chemical energy to electric energy; a dam: gravitational potential energy to kinetic energy of moving water.
3. Simple examples of storage of chemical energy are batteries and food. When food is digested and metabolized (often with oxygen), chemical energy is released, which can in turn be transformed into heat, or by muscles into kinetic energy.

Card 3

- Since the industrial revolution, the burning of coal, oil, natural gas or products derived from them has been a socially significant transformation of chemical energy into other forms of energy.
- At present, much emphasis is put on the introduction of a worldwide system to limit global emissions in greenhouse gases by balancing regional differences on a financial basis.
- Energy conservation law is a fundamental principle of physics.
- Work is done when a force causes an object to move or prevents it from moving.

Card 4

1. In order to raise the weights above his head an athlete must apply a force which causes them to move.
2. The number of joules of energy before and after a change is the same ie no energy is lost or gained.
3. Kinetic energy is the energy a body possesses because of its motion.
4. Convection is the movement of heat energy by changing of position of its particles.

Card 5

20. In an oven the burners are put at the bottom so that convection currents carry the heat to all parts.
21. At a coal, oil or gas power station the fuel which contains chemical energy is burned in order to release its energy as heat.
22. The radiant heat energy creates convection currents in the atmosphere.
23. Light energy is changed into chemical energy by a process called photosynthesis.

Card 6

1. When the water is released it loses potential energy which could be used to turn turbines and generate electricity.
2. The potential energy of a high tide is stored behind the dams and then released at low tide.
3. If a pole-vaulter sprints down a runway, just before planting the pole he will possess a lot of kinetic energy.
4. A nuclear submarine obtains its energy requirements from a nuclear reactor.

Card 7

- A catapult needs to be stretched before it will work.
- When the air is moving, its movement or kinetic energy can be used to turn the turbine and generate electricity.
- Sugar can be grown and the sugar fermented to produce alcohol which can be used as a fuel instead of petrol.
- When it rains some of the water's potential energy is kept by storing the water behind dams.

Card 8

1. When uranium-235 absorbs a neutron it becomes unstable, splits into two smaller atoms and releases a large amount of energy.
2. The movement of heat energy (and liquid), driven by a heat source, is called a convection current.
3. All metal are good conductors of heat and easily transfer energy from place to place.
4. Power is a measure of how rapidly work is being done, it's measured in watts.

Energy
Conduction
Work and power
Convection
Energy resources
Alternative sources of energy
Potential energy and kinetic energy

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